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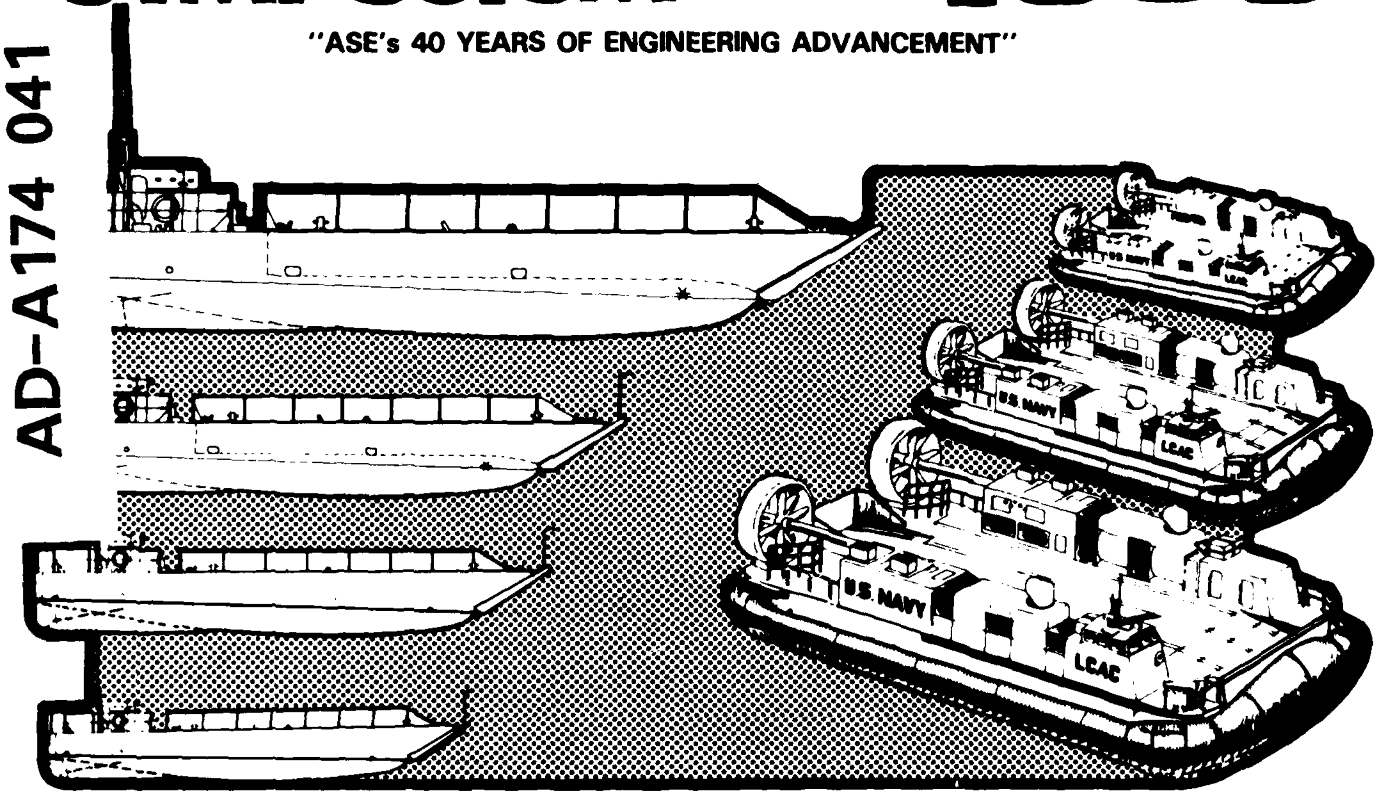

SYNTHETIC LINE SNAPBACK

by: G. Prentice

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ABSTRACT

Synthetic line snapback is a dangerous, sometimes lethal, phenomenon. Over the last decade several U.S. Navy sailors have been killed, and many more injured. There was a research and development program initiated in the early 1980s to look at this problem. This report summarizes the direction, goals, and results of this multi-service effort to reduce the danger of synthetic line snapback.

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Introduction

When a long thin tensile member is loaded until it breaks, it will ~~fly or~~ snap back in the direction of pull. It matters not if that tensile member is made of rubber, synthetic fiber, wire or glass; it is going to snap back. The only variable in this phenomenon is the speed that it will snap back.~~(1).~~ Synthetic fiber rope snaps back at about 700 feet/~~per~~ sec~~ond~~; wire rope at about 450 feet/~~per~~ sec~~ond~~. Therefore, both ropes are deadly to anyone standing near them when a failure occurs. In the early 1980's several synthetic fiber ropes did fail, and unfortunatly some of our sailors were near. In one nine month period three sailors were killed and four had one or both legs cut off. ~~The~~ following is ~~an~~ outlines ~~of~~ the approach ~~that was under~~taken by NAVSEA to reduce the number of accidents resulting from synthetic line snap back.

APPROACH

At the time we started investigating synthetic line snapback everyone knew that it was the result of the force imparted to the line by the sudden release of the stored energy when the line breaks. The exact mechanism was not known and no test existed to quantify or qualify it. We felt we had to understand that mechanism better in order to exploit it to our advantage. To accomplish this we, with the U.S. Coast Guard, undertook tests at the USCG R&D Center in Groton, Connecticut (2). They investigated three parameters to quantify the snapback behaviour:

- Storage Energy Potential, which is a measure to how much energy a line stores as a load is applied,

- Snapback Energy Potential, which is a measure of the energy that a line possesses after parting and before recoil

- Energy Release Ratio, which indicates the proportion of the stored energy that becomes kinetic energy after failure.

Ten synthetic line materials and constructions were investigated. High speed photography was used and breaking velocities and kinetic energy were determined.

While we were pursuing this endeavour we were advised by E.I. DuPont Co. that they were looking into the snapback of a line made of Kevlar. They were concerned because some rumors were emerging that Kevlar, a synthetic fiber made by Dupont that only stretches 3% to 5%, would have little or no snapback. The results of their testing showed that Kevlar line did snapback for most constructions tested. Although their report was not published at that time, a high speed movie they lent us indicated some very interesting phenomenon that we were able to later utilize and benefit from.

Several rope companies participated with us in the work we were undertaking and we tested several "low snapback" lines that were commercially available at that time.

Before synthetic fiber rope came into general use in the 1950's, manila was the material that was used almost exclusively for marine rope and line. One of the characteristics that manila has is that just before a line breaks a distinctive popping sound could be heard from the line. Although the time between the popping and the break was only 1 to 3 seconds, we were assured that a lot of distance could be covered down the deck by personnel if they knew a line was about to break behind them.

Synthetic line makes no such sound, so there is no comparable warning before failure occurs. We felt that if we could build something into the line that would give some audible signal before failure, it might be a safety feature beneficial to linehandlers. We began to look for a "talking line." Some manufacturers said they had lines that talked and others suggested some ideas to get the talking effect.

One of the first things that we did when we undertook this task was to compile all the information available on accidents. In the hope that there might be some trend evident or indication of deficiencies that would be apparent through statistical analysis (3)(4)(5).

Another possibility that we thought might be contributing to the number of accidents was personnel training. Were personnel who handled lines adequately trained for their tasks? Training manuals, course outlines and technical manuals were reviewed for content and applicability.

The inspection and replacement method utilized with line is a physical examination with comparison to photographs and written descriptions. These too were reviewed and reexamined.

RESULTS

As test results of the snapback mechanism became available and more high speed film was analysed, patterns began to develop (6). When the three strand and six strand lines broke, especially the six strand, they usually broke at one instant resulting in the full energy of parting going into snapback energy. Occasionaliy one strand would break first and cascade down the line dissipating some of the energy. On the six strand line sometimes as many as five of the strands would break in a stagger pattern. Each of these strands dissipating energy as it broke, greatly reduced the snapback energy and sometimes to such an extent that the completely parted line did not recoil back to the attachment point. In another construction, one with a cover and core, it was noted that sometimes the cover broke first and snapped back over the core, dissipating energy so that when the core broke it did not snapback as severely. We decided to try and see if we could design a line using one or both of the above phenomenom that showed reduced snapback.

A task was given to the Naval Ocean Research and Development Activity (NORDA) to design and test lines using these principles, with the aim of obtaining a truly nonsnapback line (7). Several candidate lines were made and tested. These lines included three strand Kevlar; six strand Kevlar wrapped in a long helix around a center nylon line; six strand polyester laid up around a polyester core (both of these constructions utilized line with several different helix angles); braided Kevlar made over a high elongation nylon core (different lines were made with different ratios of core diameter and line diameter, also outside covers were tried over the braid); twelve strands of load-bearing Kevlar applied in a twill braid with a nylon core that had a thin Kevlar cover. The first series of lines snapped back when tested in the a short test pit. The second series produced several samples that did not snap back. We made more of these lines and tested them in longer lengths.

Of these, some did not snapback. The next group produced were tested aboard ship, using existing capstans, bitts and chocks. In these tests several of the lines which did not snapback earlier, did so with suprising force. The most likely non-snapback line in the first set of tests was one made with a Kevlar cover and a Nylon core. Because of the limitation of the rope making machinery available,it was limited to a 150,000 pound breaking strength line. It performed so well in the pit, that we made a 200 feet piece and broke it between two USN fleet tugs. When it broke one of the ends snapped back past the pilot house of one of the tugs.

After more testing we determined that for most of the constructions, no snapback occured in pieces less than 80 feet in length. However those same lines, when broken in lengths greater than 80 feet, snap back occurred. Other samples showed no snapback in lengths under 120 feet. Subsequent field tests were done on lengths 180 feet or longer after initial laboratory testing. At this point our most promising looking candidate was a rope with a nylon core and a Kevlar cover. It was designed so that the Kevlar cover took all the tensile load until failure when it would then snap back over the nylon core. The nylon core(which was weak by comparison) would come under load and break when the load was so small that it could not carry back the Kevlar cover. In the first tests when the Kevlar broke, the heat generated melted the core and snapback occured. NORDA successfully overcame that difficulty by adding an unloaded, second, Kevlar cover that protected the nylon core from the heat. This design worked. At last we felt that we had a true nonsnapback line. Additional testing was done on lengths up to 200 feet long (8), and again no snapback occured. We cannot test every conceivable condition in the laboratory, that a line would be subjected to aboard a ship. So at the present time we are procuring one ship set of this line for fleet evaluation. The lines should be delivered sometime mid-summer of 1986 and start fleet evaluation in the fall.

Three strand nylon line snaps back at speeds of about 700 feet per second. When we tested commercially avaiiable low snapback lines we found some did snapback at lower speeds than a typical three strand nylon line, but not much lower. We did not feel that this small reduction in snapback speed was of much advantage over current lines.

The Coast Guard R&D Center tested some talking ropes. These tests were done in their laboratory with microphones along the rope. No samples tested produced sound that could be detected.

Accident reports have been statistically analysed and studied. From these results and discussions with fleet personnel it became apparent that there was a general lack of awareness of the dangers of line snapback in the fleet. We concluded that a method of making personnel more aware of the dangers present when handling lines, and how to safely handle themselves in those instances, would be a useful addition to their store of knowledge. Discussions were held with personnel from the Supervisor of Salvage office, the Naval Safety Center, Coast Guard, Navy service squadrons and fleet personnel to consider how best to accomplish this task. The conclusion reached was that a film should be made that demonstrated the dangers present and how to respond to them; and it would have to be done in such a manner

so as to catch the viewers attention and hold it. A committee was formed, a script was written and edited, a storyboard was generated and the Film was made. It was shot, compiled, edited and released in nine months. One nagging concern during the filmmaking, bothered us. We wanted to grab the viewers attention and hold it long term as well as short, but we did not want to scare them so much that they would be afraid to go near a line. To prevent this from happening we hired a communication specialist from the University of Maryland (9). She developed a test to be taken by viewers before seeing the film, and another for after the film had been seen. We tested about 100 people in Norfolk the first time. The results of these tests showed that we had indeed attracted their attention, but that we had not scared them too badly. The name of the film is "Synthetic Line Snapback" and it is in the Navy Film Library system. It has also been added to the basic enlisted personnel and officer training courses. At the present time the film is also aboard all the tankers in the Exxon and Mobil fleets.

When we first reexamined the inspection criteria of synthetic fiber rope we began to suspect there was a deficiency in Nylon line. It appeared that nylon line was somehow losing strength with time that was above and beyond what one would expect from mechanical degration and wear. A Research and Development task was given to MIT to determine if they could find this unknown flaw. Fortunately they did and they also developed a device that had a high potential of becoming a very useful device for determining the residual strength remaining in a rope. The next year should verify if it can be utilized by the fleet.

CONCLUSIONS

Synthetic line snapback is a serious problem. All people who handle lines need to be aware of it and how to lessen the danger inherent in the situation. Studies have shown that the most effective stort term solution is to make personnel aware of the dangers involved in linehandling and the proper procedure for handling the lines to avoid injury due to snapback.

For long term solution to the problem, the development of a low snapback line is the only sure way to go. A Kevlar-Nylon combination has been tested in the laboratory and will shortly undergo field testing on a U.S. Navy ship. If this line does reduce the snapback or provides enough time for personnel to clear the area, we will have succeeded.

This paper was intended only to bring an awareness of this hazardous situation to those people who have the ability to change it. The civilian engineers and military personnel of the U.S. Navy have the job of finding a solution to the problem and implementing it for the benefit of all sailors, amateur and professional.

REFERENCES

(1) Dupont, E.I., "The Effect of Loading on the Extension and Recovery of Ropes of Nylon and Dacron," Bulletin X-92 of Oct 85

(2) Bitting, Kenneth R., "A Snapback Evaluation Technique for Synthetic Line," Report No. CG-D-29-82 of May 82

(3) Davis, N.B., Davis, E.G. & Blockwich, T.N., MAR Incorporated,"An Engineering and Human Factors Analysis of the U.S. Navy's Synthetic Rope Safety Problem," Technical Report No. 312C of Nov 82

(4) Horvatic, CDR Tom, FATHOM Magazine, "The Line of Duty," Fall 1982

(5) Gallop, LT S.P., FATHOM Magazine, "Don't Hand Me That Same Old Line!" Fall 1980

(6) Feyrer, I.K., "Break Test Carried Out on Various Ropes in Order to Determine the Energy of Lash Back at Break," University of Stuttgart, Dec 78

(7) Swenson, R.C., "A Snap-Back Restrained Kevlar Mooring Line," Offshore Technology Conference Paper OTC-4636

(8) Williams, T.M., Wyle Laboratories, "Snapback from Breaking Point," Testing on three (3) mooring lines Report No. 46195-1 of 16 Aug 82

(9) Riddle, Kimberly C; MAR Incorporated, "An Empirical Evaluation of the Effectiveness of the Navy Film Synthetic Line Snapback" of Aug 82